ADVANCED WASTE TREATMENT OF SECONDARY EFFLUENT WITH ACTIVATED CARBON

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Introduction

The past decade has seen a fundamental change in our concepts of waste treatment and pollution control. Originally, the treatment of municipal wastes was primarily concerned with the preservation of public health. Next we become concerned with esthetic concepts such as the elimination of visible signs of pollution and the maintenance of oxygen levels for sustenance of marine life in receiving waters. In the last decade two new concepts have been developed. The first is that in many areas water is becoming scarce so that it may be necessary to use water more than once. The second is that natural waters should be maintained in a condition of purity so that the overall impact of water use on the environment is minimized. Both of these concepts require treatment of wastewaters that is fundamentally different from the treatment that was acceptable at a time when our only concerns were with public health, esthetics, and oxygen depletion. In this context activated carbon adsorption is the key unit process in the treatment of wastewater to produce effluents meeting our present requirement for effluent quality and receiving water preservation.

The use of coal in water treatment goes back to the last century. In 1883, 22 water plants in the United States were reported to be employing charcoal filters. These were later abandoned because of the low adsorptive capacity of the charcoal. The production of activated carbon was started in 1913 by a predecessor of Westvaco. However, its first recorded application to municipal water treatment was not until 1927 when two Chicago meat packing companies used powdered activated carbon to remove tastes from their water supplies. During the 1930's, the use of powdered activated carbon to remove tastes and odors caused by traces of dissolved organics spread rapidly.

In 1960, the U. S. Public Health Service embarked on the Advanced Waste Treatment Research Program with two stated goals - to help abate water pollution problems and, more startling in concept, to renovate water for direct and deliberate reuse. The program focused early on adsorption as the most promising process for achieving its stated goals, and on activated carbon as the most feasible adsorbant. A series of studies were commissioned by the Public Health Service and, since 1966, the Federal Water Pollution Control Administration, to evaluate the feasibility of activated carbon adsorption for wastewater renovation. These studies concentrated on two aspects - the physical configuration for the most economical use of the adsorptive properties of the carbon and the reactivation of the carbon for reuse.

Based on results of these studies, several demonstration plants were designed to obtain data from commercial equipment. One of these plants is a joint effort of the County Sanitation Districts of Los Angeles County and the Federal Water Pollution Control Administration and is located at Pomona, California. The plant includes five carbon contactors and has a capacity of 400 gpm. A second plant is located at Lake Tahoe, California and is operated by the South Tahoe Public Utility District. The plant has a capacity of 7.5 mgd. A third plant, located on Long Island, New York, is the subject of this paper.

Background

Nassau County occupies 291 sq. mi. of Long Island immediately adjacent to the City of New York. During the last two decades, the County has experienced an explosive growth of population and water consumption. Since the County's only source of water supply is the local ground water, whose safe yield is limited by its rate of recharge, the continuation of this growth presages a crisis in water supply. Over-pumping results in lowering of the ground water levels and intrusion of salt water in the aquifer.

Development of the County has also decreased the rate of recharge of the ground waters. The installation of public sewer system diverts wastewater previously recharged into the ground through septic tanks and cesspools to ocean outfalls. Present projections indicate that, if present trends continue, the net amount of water withdrawn from the aquifers will exceed the rate of recharge by 1977.

One plan to increase the permissible withdrawals is to create a hydraulic barrier in the aquifer. This barrier would prevent a natural outflow in the aquifer, estimated to be of the order of 30 mgd which is now lost to the sea. It would also prevent the intrusion of salt water into the aquifer which is already becoming a problem in some areas of Nassau County. The barrier would be formed by injecting tertiary treated wastewater through a series of recharge wells along the southern perimeter of Nassau County.

Water Quality Requirements

In order to provide water of a quality necessary for injection into public water supply aquifers, the effluent of the existing sewage treatment plant must receive additional treatment to meet the following requirements:

1. U. S. Public Health Service Standards for drinking water.
2. Economical operation of injection system.
3. Chemical compatability with natural ground water.

The drinking water standard was adopted primarily in order to gain public acceptance of the concept of injecting treated wastewater into an aquifer which is used as a source of public water supply. Present plans provide for maintaining at least one mile separation between injection and water supply wells. This distance will insure that no particulates or bacteria will reach the water supply wells. Nevertheless, it was decided as a policy matter that the water as injected must meet the standards for drinking water.

Advanced Waste Treatment Process

The advanced waste treatment process used to achieve these water quality criteria consists of coagulation with alum, filtration, adsorption on activated carbon and disinfection with chlorine.

Standards of water quality for economical operation of the injection system are being developed as part of the demonstration project. From injection tests conducted thus far, it is apparent that particulates must be maintained at the lowest possible level. Turbidity levels of less than 0.5 J.U. appear to be desirable. Low levels of dissolved gases were considered desirable during the early stages of the project but do not appear to be as critical as they were thought to be. Turbidities in excess of 1.0 Jackson Units result in rapid buildup of pressure required to inject at a given rate of flow.

The principal problems of compatibility involve iron and phosphate concentrations. Iron precipitates in the aquifer, causing irreversible clogging of the formation. The role of phosphates is not yet fully understood. However, changes in phosphate concentration between water injected and injected water recovered have been observed, leading to the conclusion that phosphates interact with the fine clayey sands that comprise the aquifer.

Effluent from the final sedimentation tanks of the Bay Park Sewage Treatment Plant is pumped into a clarifier, where alum and coagulant aids are added. Sludge recirculation is employed to improve coagulation and overcome sudden changes in water quality. Flow then passes by gravity to two mixed media filters operated in parallel, each containing a 36-inch bed of anthracite above a 12-inch layer of sand. Filter backwash is automatic, and includes facilities for air scour, surface wash, and high and low rate backwashing.

Filter effluent is pumped through four granular activated carbon adsorbers operating in series. Adsorber piping is arranged so that the order of the vessels can be rotated to change the sequence of flow and insure the most efficient utilization of carbon. Upon exhaustion, carbon is moved hydraulically to a regeneration system. Here the carbon is restored to its original activity by controlled burning off of the adsorbed organics in a multi-hearth furnace.

The renovated water is disinfected with chlorine prior to being pumped about one half mile to the test injection site. The injection facilities consist of a storage tank, degasifier for removal of residual chlorine and dissolved gases, injection and redevelopment pumps, the injection well and 12 observation wells. The injection well is 36 inches in diameter by 500 ft. deep, and contains an 18 inch casing which supports a 16 inch screen set between elevations - 420 and 480 ft. The annular space surrounding the screen has been backfilled with graded sand and contains an observation well and geophysical probes. Other observation wells are located up to 200 ft. from the injection well.

Carbon Adsorption System

The design of a carbon adsorption system for the treatment of wastewaters involves consideration of the following parameters:

Type of carbon - granular or powdered
Physical configuration - upflow or downflow, or mixed number of stages, parallel or series, packed bed or expanded bed, external regeneration or continuous flow
Carbon capacity - detention time, dosage rate
Method of operation - pure adsorption, filtration, biochemical

For the Nassau County project, granular carbon was selected over powdered carbon primarily because of the state of the art of carbon regeneration. Powdered carbon has some advantages over granular carbon. Its initial cost is lower, 7½ cents per pound against 30 cents for granular carbon. It reacts faster and more completely, and its dosage can be adjusted to meet changes in the composition of the influent to the system. On the other hand, even the cost of powdered carbon is not sufficiently low to permit its discard after a single use. Some experimental work is now in progress on powdered carbon regeneration, but it has not yet reached the stage where a full scale demonstration plant can be designed. Dewatering and incineration are the most feasible methods of disposal of waste powdered carbon.

Granular carbon has been in industrial use for many years and the technology for its regeneration is well established. It has the additional advantage of providing a margin of safety in operation that powdered carbon does not provide. Sudden changes in influent composition are common in wastewater treatment. If the dosage of powdered carbon is not adjusted to meet these changes, the effluent quality will reflect the insufficient dosage. Granular carbon has the capacity to withstand substantial changes in the influent composition with a much reduced effect on the effluent quality. This aspect and the availability of the regeneration technology were the major factors in the selection of granular carbon for the Bay Park project.

Even after the choice has been made between granular and powdered carbon, some further selectivity is required. Activated carbons are manufactured from a variety of raw materials such as coal, wood, nut shells and pulping wastes. A carbon that must undergo multiple regenerations must have the capability of being handled with a minimum of deterioration or abrasion. Since coal derived carbons are harder and denser than other carbons, this type of carbon was specified for the Bay Park project.

As a result of operating experience the additional requirement that the carbon contain less than 0.5% of iron by weight has been added.

The limit on the iron also forced a change in the gradation, so that the specifications for carbon could be met with a commercially available product. The original carbon had a size range of 8 x 30 (passing a standard No. 8 mesh sieve, but retained on a No. 30 sieve). The replacement carbon has a size range of 14 x 40.

A number of physical configurations have been suggested for activated carbon adsorption systems. These include upflow-expanded bed, upflow-compacted bed, downflow-single stage, downflow-multistage, and a quasi-countercurrent system, in which the flow is down in the first unit and up in the second unit, exhausted carbon being continuously removed in the first unit and regenerated or makeup carbon being added continuously in the second.

Upflow systems have the advantages of being less susceptible to plugging and more adaptible to continuous countercurrent operations, which in theory yield the most efficient carbon utilization. Downflow systems require periodic backwashing to prevent the buildup of headloss and multistaging to approach countercurrent operation. The differences in equipment costs are of a second order compared with the costs of regeneration and makeup. Downflow systems are mechanically simpler and have greater flexibility as to rates of flow that can be applied. For the Nassau County project, a four-stage downflow system was selected. The four vessels containing the carbon are piped so that they are in series, with each unit capable of being the lead unit. In normal operation, the flow is applied to the vessel containing carbon closest to exhaustion. As it passes from unit to unit, it encounters successively more active carbon, until in the last unit is passes through the most recently regenerated carbon.

When the organic content of the product water starts to exceed the desired level, the first unit is taken off the line and the carbon in this unit is transferred hydraulically to the dewatering tank of the carbon regeneration system. As soon as the transfer is completed, regenerated and makeup carbon from the storage tank is pumped back into the unit. The unit is then put back on the line, but in the last position in the sequence. In this manner, the countercurrent mode of the operation is maintained.

Laboratory bench and pilot plant studies were relied upon to furnish other design data. Laboratory bench studies were used to derive adsorption isotherms, which give some indications as to carbon dosage. Column tests were then used to determine the required contact time. The hydraulic loading then becomes a matter of convenience for the design of the equipment. For the Nassau County project, the following design parameters were adopted, based on over a year's pilot plant operations:

Total contact time (empty bed volume) 24 min
Hydraulic Loading (approach velocity) 7.5 gpm/sq ft.

The combination of these factors resulted in a vessel diameter of 8 ft and a bed depth of 6 ft in each vessel. Each of the vessels contains 300 cu ft or about 9,000 lb of carbon. The rate of exhaustion has been about 800 gal per pound of carbon or 1.25 lb per 1000 gal treated.

Economics

Unit costs for the advanced waste treatment process are given in the following table. The table is based on a COD reduction 90% from 50 mg/l in the secondary effluent to 5 mg/l in the product water and a phosphate reduction of 90% from 30 mg/l (as PO_4) to 3 mg/l.

Estimated Unit Costs

	Plant Capacity		
Cents per 1000 gal	1 mgd	10 mgd	100 mgd
Process costs, less labor			
Coagulation	4.9	3.5	3.2
Filtration	1.8	1.1	1.0
Carbon adsorption	6.3	4.5	4.0
	13.0	9.1	8.2
Operating labor	28.0	5.6	1.8
	41.0	14.7	10.0

Annual charges have been assumed at 8.5% of the capital costs and include both debt service and an allowance for maintenance, repair and replacement. Unit costs also assume continuous operation at design capacity (100% load factor). The costs are for treatment only and do not include transmission or injection facilities.

Conclusions

The Nassau County project is demonstrating the feasibility of treating secondary effluent with a physiochemical process sequence involving activated carbon to remove organics resistant to biological treatment. The product water meets U.S. Public Health Service Standards for drinking water and has physical properties such as turbidity, color or odor equivalent to those of the domestic water supply. It can be recharged into the ground without causing any deterioration of the aquifer. Based on test operations now in progress, it is believed that the concept of using treated wastewater for hydraulic barriers against seawater intrusion is technically feasible.

The project opens up new potentials for water reuse in areas where fresh water supplies are acarce. Wastewater is always available where there are public water supply and sewerage systems. Newly adopted water quality standards will require many communities to provide more than conventional secondary treatment. With activated carbon treatment, the product water can now be made available for many forms of beneficial reuse requiring high quality water.

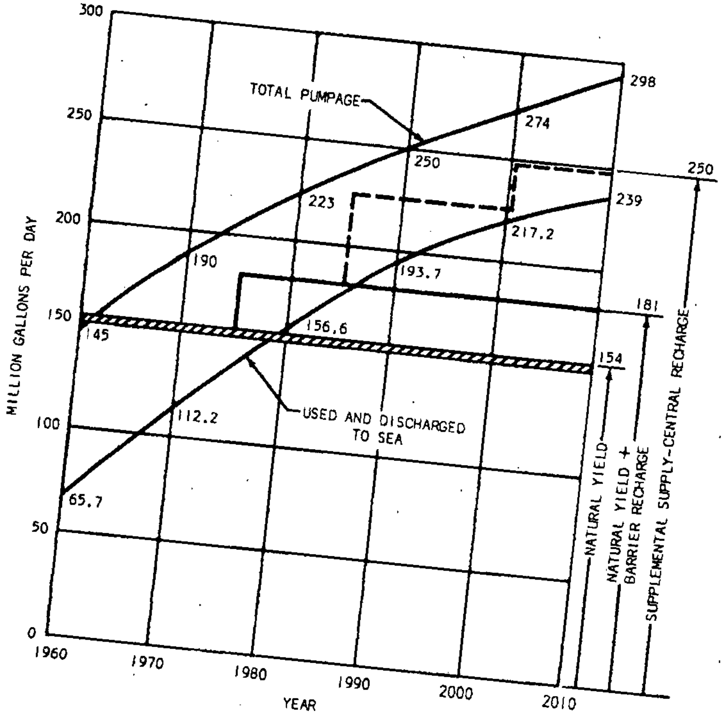

Figure 1
Water Requirements and Supply

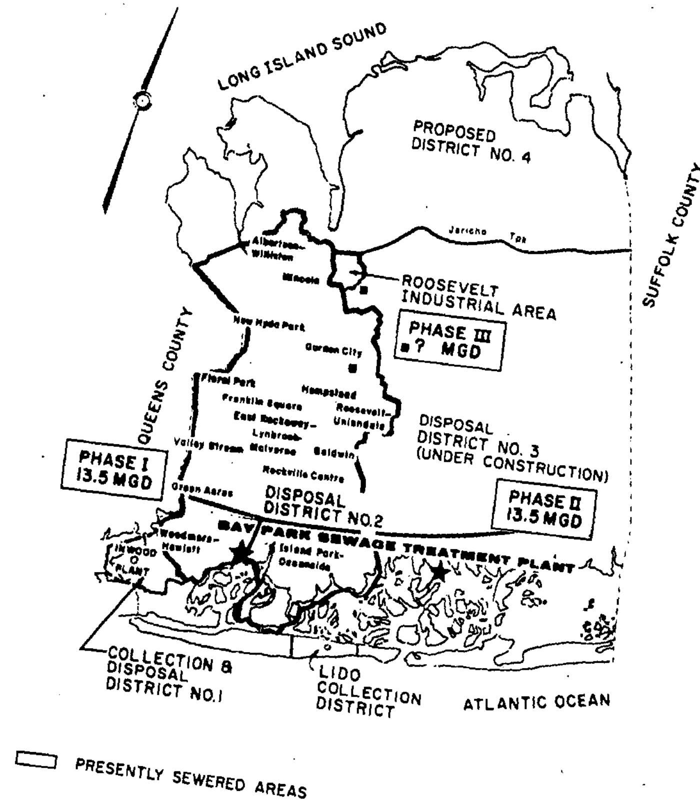

Figure 2
Proposed Recharge System

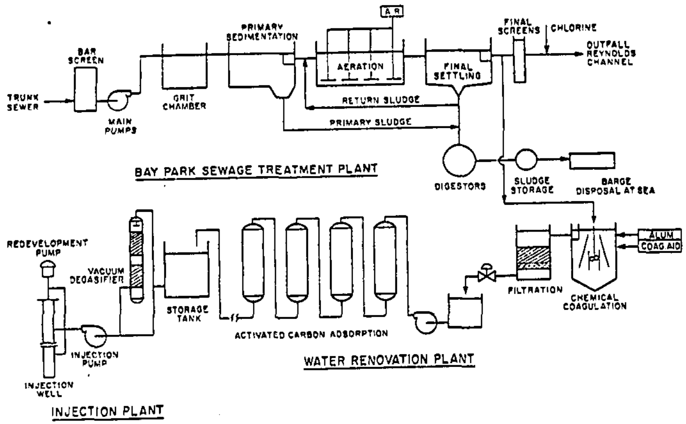

Figure 3
Flow Diagram

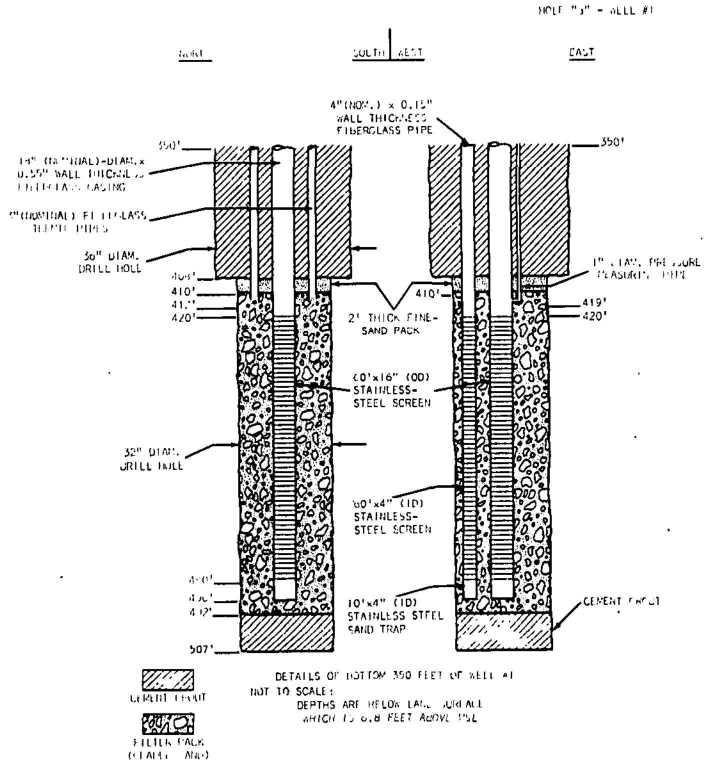

Figure 4
Sections Through Injection Well